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The Mid-Cretaceous transgression onto the Central Polish Uplands (marginal part of the Central European Basin)

By

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With 6 text figures, 8 plates and 1 table

ABSTRACT

The Central Polish Uplands belonged to the south-eastern marginal parts of the Central European Basin during the mid-Cretaceous transgression. The topography of the Kimmerian tilted substrate controlled not only the transgressing sea but also the extent of the shoreline and the paleoenvironments of the mostly sublittoral successions. The transgressive deposits from the Middle Albian *eodentatus* Subzone until the Late Turonian *Inoceramus costellatus* Zone reflect the gradual filling of the basins and the effects of synsedimentary movements: either regional block-faulting (Cracow Upland in the southern part of the Polish Jura) or a continous uplift of submarine swells (Polish Jura Swell, Annopol Swell). Four pulses can be recognized within the mid-Cretaceous transgressive sequence. None of them is truly regressive, but all are particular episodes of one transgressive cycle. Abundant faunas particularly in phosphatic beds allow paleobiogeographical and environmental conclusions with a special contribution to the phosphorite beds of Annopol-on-Vistula. Boreal and Tethyan affinities in the ammonite faunas are briefly discussed with some remarks on the extents of the two bioprovinces.

KURZFASSUNG

Das polnische Mittelgebirge gehörte zur Zeit der Mittelkreide-Transgression zum südöstlichen Randbereich des zentraleuropäischen Beckens. Die Topographie des jungkimmerisch verstellten jurassischen Untergrundes kontrollierte nicht nur den Ablauf der Transgression, sondern auch die Entwicklung der Küstenlinien und die Abfolge der überwiegend sublitoralen Sedimentation. Die transgressiven Ablagerungen von der *eodentatus* Subzone des mittleren Albs an bis zur *Inoceramus costellatus* Zone des obersten Turon spiegeln die allmähliche Auffüllung der Becken und die Auswirkungen der synsedimentären tektonischen Bewegungen wider: es sind teils regionale Bruchtektonik (Krakauer Hügelland im südlichen Teil des polnischen Jura), teils ein allmählicher Aufstieg submariner Schwellen (Polnische Jura Schwelle, Annopol-Schwelle). Es sind vier Phasen innerhalb der Mittelkreide-Transgression erkennbar; keine davon ist wirklich regressiv, sondern sie gehören einem transgressiven Zyklus an. Die reichen Faunen aus den Phosporiten ermöglichen detaillierte Aussagen zur Ökologie und zur Genese der Phosphoritvorkommen von Annopol/Weichsel. Anhand der Ammonitenfaunen werden die paläobiogeographischen Beziehungen zwischen borealer und Tethys-Faunenprovinz und die Einflüsse beider Faunenprovinzen auf das zentraleuropäische Becken diskutiert.

INTRODUCTION

The area of the Central Polish Uplands belongs to the south-eastern marginal parts of the Central European Basin. This marginal nature resulted from an elevated zone along the northern outskirts of the Alpino-Carpathian geosyncline. In Poland this zone has commonly been regarded as a more or less hypothetical meta-Carpathian arch. During Mesozoic time it temporarily separated the Carpathian flysch geosyncline from the epicontinental basins to the north. In the Early Albian parts of the meta-Carpathian arch had been uplifted, supplying coarse clastic material both to the south (towards the Carpathian flysch geosyncline) and to the north (onto the Central Poland Uplands area). The mid-Cretaceous trans-

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gressive sequence has thus a primarily clastic character. It lies with a stratigraphic gap on the pre-Albian land topography. On the other hand, the morphology of the meta-Carpathian arch mostly resulted from the New-Kimmerian epeirogenesis, which was responsible both for the tectonic tilt (in the range of a few degrees) and the erosion of the Upper Jurassic sequence completed by the Tithonian (Volgian) decline (Kutek & Zeiss 1974). Consequently the investigated mid-Cretaceous sequence, regardless the Neocomian sedimentary episode further to the north, rests upon eroded Oxfordian or Kimmeridgian substrate in most of the Central Polish Uplands area.

The mid-Cretaceous sequence exposed in many exposures in the Central Polish Uplands embraced the time interval from the Middle and Upper Albian to the Upper Turonian. Its deposition took place within the paleogeographic frames of the Central European Basin. It was basically controlled by the geotectonic development and subsidence of the Danish-Polish Trough to which the majority of the Polish territories (except the Carpathian geosyncline) have belonged during the post-Variscan (Alpine) tectogenic cycle.

GEOTECTONIC SETTING AND FORMATION OF THE CENTRAL POLISH UPLANDS

The development of the Danish-Polish Trough started in early post-Variscan time. Little is known of its Variscan substrate which has been deeply subsided and covered by a 6–8 km thick series of deposits, and therefore it is rarely reached by boreholes. The trough itself was filled by a complete sequence of Permian (mostly Zechstein) to uppermost Cretaceous deposits. The thickness is greatest along a rather narrow zone which signifies the axis of the trough: Zechstein over 1000 m, Triassic over 2000 m, Jurassic over 2000 m, Lower Cretaceous (Neocomian) over 500 m, and Middle and Upper Cretaceous over 2000 m. The Danish-Polish Trough – established along the south-western margin of the Fenno-Sarmatian Shield (the East European Platform) – represents a pericratonic zone of the aulacogen type (Kutek & Glazek 1972; Radwanski 1975; Ziegler 1975). Its sedimentary sequence was mostly marine, and was laid down under shallow sublittoral and neritic conditions. The marine intervals were interfingering with a few nonmarine series developed during the regressive phases connected with the Old- and New-Kimmerian epeirogenesis. The latter resulted in termination of the Upper Jurassic marine cycle with the Purbeck and Weald series.

The axis of the Danish-Polish Trough parallels the south-western margin of the Fenno-Sarmatian Shield, and reflects a zone of deeper fractures, supposedly of rift character, both in the Earth crust and in the upper mantle (Guterch 1968, 1977). A tectonic uplift along this strongly subsiding axis took place in the Maestrichtian (Laramide phase of the Alpine cycle), resulting in the formation of the Mid-Polish Anticlinorium which divided the trough into the Szczecin-Lodz-Miechow Synclinorium, and the Danish-Polish (Gdansk-Warszawa-Lublin) Synclinorium, or Border Synclinorium (Kutek & Glazek 1972), for it borders the Fenno-Sarmatian Shield. In this synclinorial zone, comprising the Danish Embayment area sensu Larsen (1966), the regressive sea continued as late as the Upper Danian (Hansen 1970); the stage is represented by marine deposits in this zone, both in Denmark and in Poland. The elevated zone of the Mid-Polish Anticlinorium corresponds in Denmark to the Ringkobing-Fyn-High (Larsen 1966; Christensen 1976).

The direction of the axis of the Mid-Polish Anticlinorium determines only the zone of maximum subsidence of the basin, whilst the facies distribution and paleogeographic trends during the Mesozoic marine invasions were controlled by a latitudinal direction of the Central European Basin. This is clearly shown by successive, eastwardly extending transgressions of the Zechstein, Triassic (Röt-Muschelkalk), Lower Jurassic (Pliensbachian and Lower Toarcian only), Middle and Upper Jurassic, Neocomian (Valanginian and Hauterivian), and finally of the Albian/Cenomanian till the Danian. The southward extent of some deposits seems to have been controlled by that very direction, e. g. in Liassic alluvial or intertidal series, Neocomian transgression, and (Kutek & Glazek 1972, fig. 12) in the first stages of the Albian transgression.

The Holy Cross Mts belong also to the axial zone of the Danish-Polish Trough. Their Variscan core has been exposed by erosion which followed their maximal uplift. This latter has been caused not only by the Laramide uplift of the Mid-Polish Anticlinorium, – which was insufficient to expose the Variscan series for at least ca. 3 km of Mesozoic deposits had to be removed, – but also by another uplift, the circum-Carpathian one. The intersection of the two uplift zones resulted in successive processes of elevation and degradation that finally led to the denudation of Paleozoic basement of the Holy Cross Mts. The restored cross-sections through the Holy Cross region during Mesozoic time (Kutek & Glazek 1972, figs. 5 and 6) evidently show that neither a land nor a submarine ridge existed at that time: the Variscan orogenic belt of the Holy Cross Mts had strongly been subducted along the Danish-Polish Trough.

The uplift of the circum-Carpathian zone at the northern margin of the Fore-Carpathian Miocene Depression was an isostatic response to the subsidence of the Depression. This uplift is responsible for the formation of the Central Polish Uplands, a hilly belt that repeats the outline of the Carpathians and their foredeep (fig. 1). The zone of the Central Polish Uplands embraces from the west successively: Upper Silesia, Polish Jura (with Cracow Upland as its southernmost part), Miechow Upland, Holy Cross Mts, and finally the Lublin Upland situated at the eastern end of the zone.

Due to the Laramide uplift and the subsequent erosion, the mid-Cretaceous transgressive deposits appeared at the surface along the Central Polish Uplands. The numerous exposures

Fig. 1. Tectonic sketch-map of Poland (without Quaternary and continental Tertiary cover), to show geotectonic setting of the Central Polish Uplands; areas of Cretaceous deposits under the Quaternary and continental Tertiary cover are stippled; axial zones of the main Laramide tectonic units are indicated. Within the Central Polish Uplands indicated are: *US* – Upper Silesia, *PJ* – Polish Jura; *CU* – Cracow Upland (southernmost part of the Polish Jura); *MU* – Miechow Upland; *HCM* – Holy Cross Mountains; *LU* – Lublin Upland.
Within the Fore-Carpathian Depression, its southern margin is delimited by the Carpathian overthursts, whilst the northern margin is taken as the extent of shoreline of the Middle Miocene (Badenian) sea. Broken lines labelled *F-S Shield* indicate a generalized outline of stable margins of the Fenno-Sarmatian Shield ("Tornquist Line"), seismically recognizable within the basement of the Danish-Polish Trough. Abbreviated are the names of localities discussed in the text: *A* – Annopol-on-Vistula; *B* – Biala Gora near Tomaszow; *C* – Mt. Chelmowa near Przedborz; *S* – Mt. Zajecza at Skotniki near Busko; *Bs* – Bystrzyca near Lublin; *L* – Lebork near Gdansk.

have been investigated for a long time (Samsonowicz 1925; Marcinowski 1974) and supplied rich and stratigraphically important ammonites and belemnites (pls. 4–7), other invertebrates (pl. 3) and vertebrates (pl. 8). All these fossils, often obscured by phosphatization, allow to recognize the condensed nature of the mid-Cretaceous sequence.

The Polish Jura and the Holy Cross Mts are the most representative regions. The other parts of the Central Polish Uplands do not offer sufficient informations about the mid-Cretaceous events: Upper Silesia has been stripped of the Cretaceous cover; Miechow Upland belongs to the synclinorial zone (Szczecin-Lodz-Miechow Synclinorium) with Upper Cretaceous deposits still at the surface, just as well as the Lublin Upland (Border Synclinorium), except of its westernmost tips (the famous exposures at Annopol-on-Vistula) which are included into the following description of the Holy Cross area.

The stratigraphic subdivision of the investigated mid-Cretaceous transgressive sequence is based on ammonites and inoceramids (table 1; Marcinowski 1974, 1975, 1980). This sequence ends with the *Inoceramus costellatus* Zone, the upper boundary of which is regarded as identical with that of the Turonian. The *Inoceramus schloenbachi* Zone is included into the Coniacian (Seibertz 1979; Naidin 1981).

The mid-Cretaceous of the other parts of the Danish-Polish Trough, north of the Central Polish Uplands, is known only by boreholes. The transgressive deposits are developed in a more or less similar array (Cieslinski 1976), although the thickness of deposits is generally greater, especially along the axial zone of the trough (Kutek & Glazek 1972; Cieslinski 1976).

TURONIAN	Upper	Inoceramus costellatus
	Middle	Inoceramus lamarcki
	Lower	Inoceramus labiatus
CENOMANIAN	Upper	Sciponoceras gracile
		Eucalycoceras pentagonum
	Middle	Acanthoceras jukesbrownei
		Turrilites acutus
		Turrilites costatus
	Lower	Mantelliceras ex gr. dixoni
		Mantelliceras saxbii
		Neostlingoceras carcitanense
ALBIAN	Upper	Stoliczkaia dispar
		Mortoniceras inflatum
	Middle	Euhoplites lautus
		Euhoplites loricatus
		Hoplites dentatus

Table 1. Stratigraphic subdivision of the mid-Cretaceous transgressive sequence in the Central Polish Uplands.

POLISH JURA

The Polish Jura shows the mid-Cretaceous transgressive sequence (Marcinowski 1970, 1972, 1974; Glazek, Marcinowski & Wierzbowski 1971; Marcinowski & Szulczewski 1972; Marcinowski & Wierzbowski 1975; Marcinowski & Radwanski 1979) accessible either in natural exposures (pl. 1) or in numerous quarries (Upper Jurassic limestones) and sand-pits (pl. 2, fig. 1–3). The sequence is generally thinning and wedging out to the south (fig. 4) and has its maximum in the north.

The Upper (possibly including uppermost Middle Albian) Albian deposits are composed of non calcareous, glauconitic sands, locally cross-bedded (pl. 2, fig. 2a–2b), which contain lenticular or irregular bodies of siliceous and quartzitic sandstones with a specific bivalve fauna: *Inoceramus concentricus* Parkinson, *I. anglicus* Woods, *I. anglicus-crippsi* m. f., and *Aucellina gryphaeoides* (Sowerby). The thickness varies from 50–40 m to 0 dependent upon the topography of the underlying Upper Jurassic (figs. 2–4). The latter are mostly massive, butten limestones in which the New-Kimmerian tilt is not discernible.

The Cenomanian is developed as marly sands and sandstones in the northern region, and coarse-grained sands or gravelstones in the south. In both cases, it usually contains rich assemblages of diverse fossils, glauconite, and phosphatic nodules. In the southern region (Cracow Upland) it often rests with abrasion surfaces directly upon the Upper Jurassic; the Jurassic limestones are bored by various rock-borers, the marls are sculptured by gregarious burrowers (Glazek, Marcinowski & Wierzbowski 1971; Marcinowski & Wierzbowski 1975). The thickness reaches 2 m, whereas in the north it ranges from 3 to 9 m. The rich ammonite fauna that comprises i. a. *Sciponoceras baculoide* (Mantell), *Hypoturrilites gravesianus* (d'Orbigny), *H. tuberculatus* (Bosc), *Mariella lewesiensis* (Spath), *Turrilites costatus* Lamarck, *T. acutus* Passy, *Scaphites obliquus* (Sowerby) *S. equalis* Sowerby, *Hyphoplites campichei* Spath, *H. falcatus* (Mantell), *Schloenbachia varians* (Sowerby), *S. coupei* (Brongniart), *S.* cf. *lymense* (Spath), *Mantelliceras tuberculatum* (Mantell), *M. saxbii* (Sharpe), *M.* ex gr. *dixoni* Spath, *Calycoceras* aff. *lotzei* Wiedmann, *Acanthoceras* sp., evidences the whole Cenomanian. Its strong condensation, apart from the often mixed faunas, obscures the zonal boundaries in some sections. All fossils are more or less phosphatized, especially the ammonites, whilst the non-ammonite fauna (Marcinowski 1974; Maczynska 1977) is often also glauconitized. In the less condensed sections, it has been shown that *Actinocamax primus* Arkhangelsky and *A. plenus* (Blainville) coexist in one bed (unit 2c, Glanow; see fig. 3), obviously below the first occurrence of *Inoceramus labiatus* Schlotheim (Marcinowski 1972, 1974).

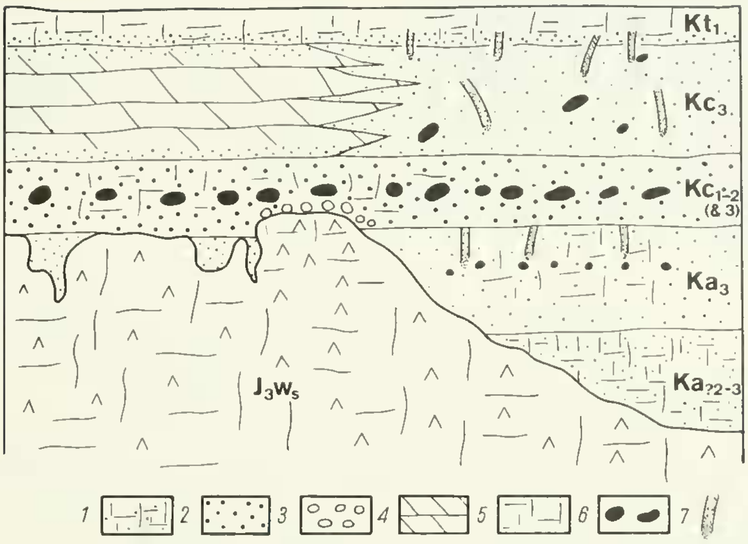

Fig. 2. Diagrammatic section of the mid-Cretaceous transgressive sequence near Mokrzesz in the Polish Jura (cf. fig. 4), to show overlapping of particular members and their relation to the Upper Jurassic substrate (Oxfordian butten limestones, J_3w_s): Ka_{+2-3} – uppermost Middle or Upper Albian; Ka_3 – Upper Albian; $Kc_{1-2/\&3/}$ – Lower and Middle, locally also Upper Cenomanian; Kc_3 – Upper Cenomanian; Kt_1 – Lower Turonian.
1 – sandstones; *2* – sands; *3* – gravels; *4* gaizes; *5* – layered limestones; *6* – phosphatic nodules; *7* – burrows *Ophiomorpha nodosa* LUNDGREN.

At the Cenomanian/Turonian boundary a synsedimentary block-faulting caused (particularly in the Cracow Upland) depressing or uplifting of particular regions. The changes in seafloor topography and associated disturbances in sedimentation lasted until the tectonic lull at the Late Turonian (fig. 4).

The subdivision of the Turonian sequence is tripartite: the Lower Turonian comprises the *I. labiatus* Zone, the Middle – the *I. lamarcki* and the Upper the *I. costellatus* Zones. In the northern region, it continues from the Cenomanian and is developed as limestones (1.5–2.7 m thick), sandy at their base. In the Cracow Upland, sandy or pebbly limestones (0–11 m) either truncate the older mid-Cretaceous deposits, or encroach directly on the Upper Jurassic (fig. 4). At the top of the sequence, a hardground, locally associated with stromatolites, indicates a high-energy, shallow subtidal environment (MARCINOWSKI & SZULCZEWSKI 1972). A regional hiatus, resulting from submarine non-deposition above the hardground and/or stromatolites, ranges from the Upper Turonian to the Lower Campanian in the north, and the uppermost Turonian to the Santonian at the city of Cracow itself. The basal Santonian deposits are sandy glauconitic marlstones (marly greensand) with small phosphatic nodules and a diversified fauna.

The area of the Polish Jura is thought to have been a submarine swell during the mid-Cretaceous transgression (MARCINOWSKI 1974) due to the presence of stratigraphic gaps, abrasion and condensation phenomena. It was caused by Subhercynian tectonic movements which are responsible for an uplift of this area during Middle and early Upper Cretaceous time. This swell, called here the **Polish Jura Swell**, was more or less parallel to the axial zone of the Danish-Polish Trough.

The Polish Jura Swell was separating the Miechow and the Holy Cross areas to the east from the Opole area in the Sude-

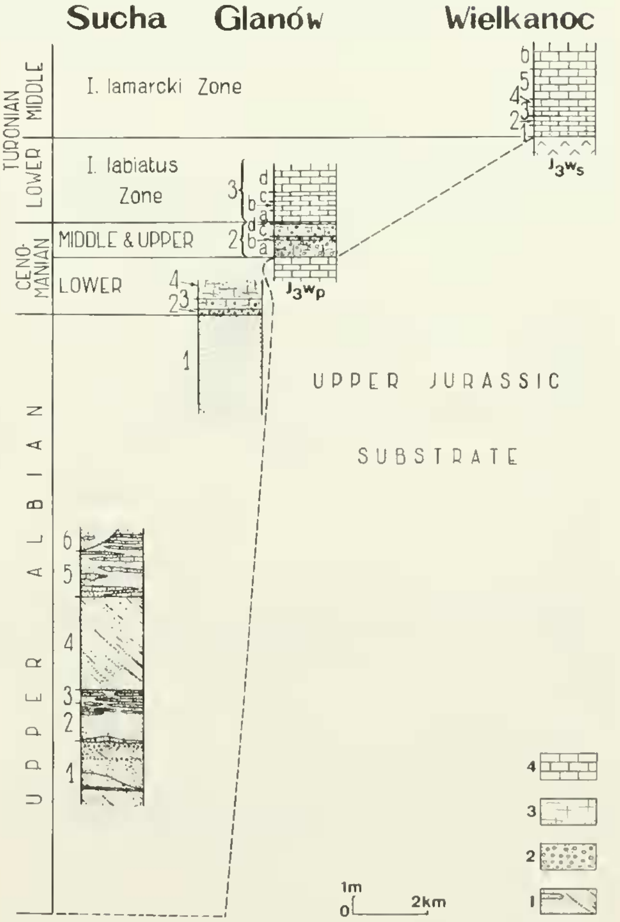

Fig. 3. Relation of the mid-Cretaceous transgressive sequence to the Upper Jurassic substrate (butten – J_3w_s or platy limestones – J_3w_p; numbers of beds the same as in MARCINOWSKI 1974) near Glanow (cf. fig. 4 and pl. 1A–D) and neighbouring locality Sucha (cf. pl. 2, Figs. 2a–b) in the Polish Jura.
1 – sands with sandstone lenses, locally cross-bedded; *2* – sandy gravelstones; *3* – marly sandstones; *4* – limestones.

tic Foreland to the west. Beginning during the Cenomanian, the subsidence of the Holy Cross area (Kutek & Glazek 1972; Hakenberg 1978), and the Opole area (Alexandrowicz & Radwan 1973), was remarkably stronger, than along the swell and resulted in increasing thicknesses of deposits (fig. 5). This stronger subsidence was presumably compensated by an almost persistent uplift of the swell, which during Upper Turonian to Santonian time became the most elevated zone within the southern margins of the Central European Basin in Poland.

To the Polish Jura Swell probably the Upper Silesia region or at least its eastern parts belonged during the discussed Upper Cretaceous time. Its Middle and Upper Cretaceous cover has completely been removed by the post-Laramide erosion. The only present-day remnants are all situated further to the west, within the subsiding zone of the Opole and Glubczyce (Leobschütz) areas (Roemer 1870; Alexandrowicz & Radwan 1973).

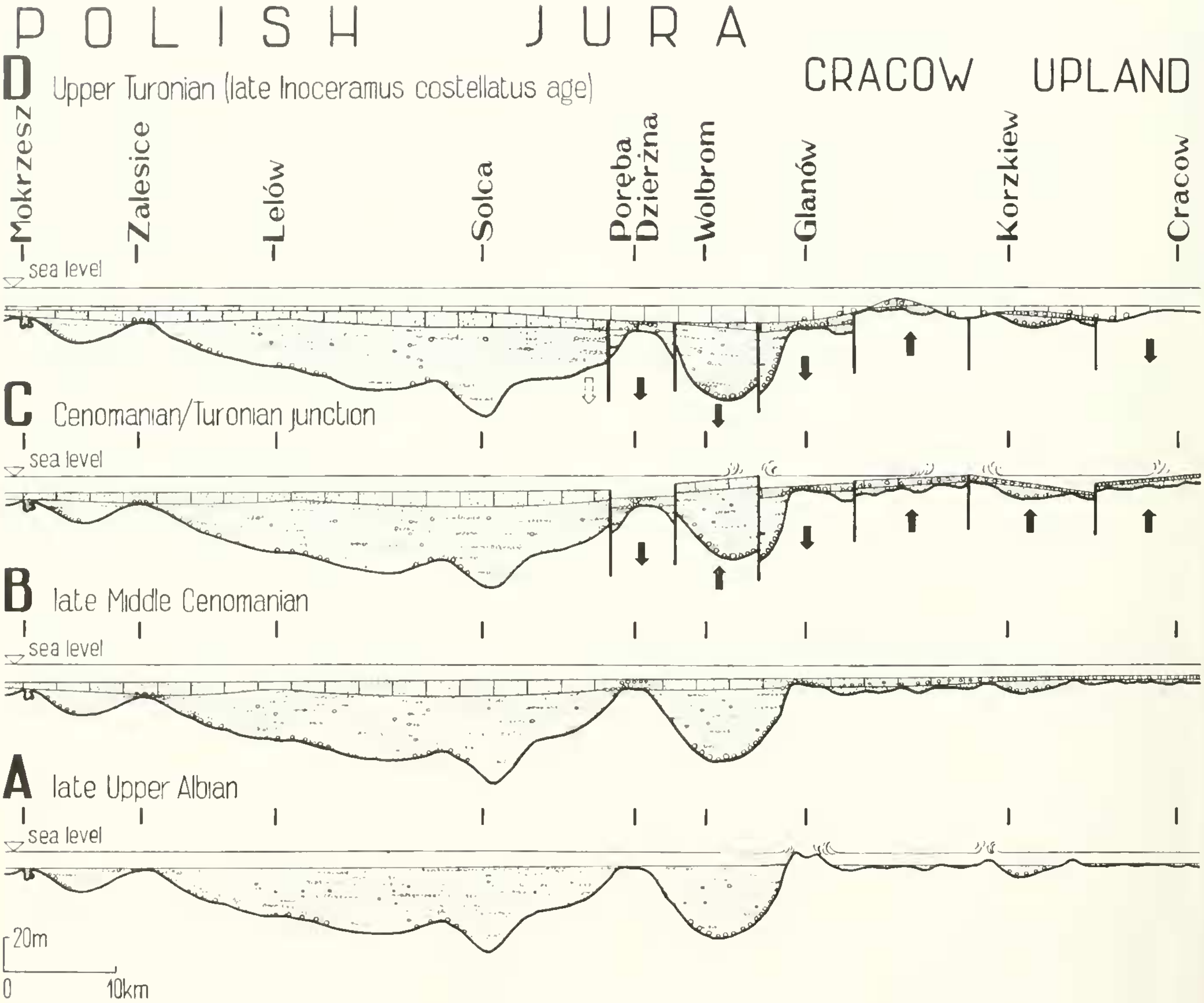

Fig. 4. Idealized successive stages *(A–D)* of development of the mid-Cretaceous transgressive sequence in the Polish Jura (lithology the same as in figs. 2–3).

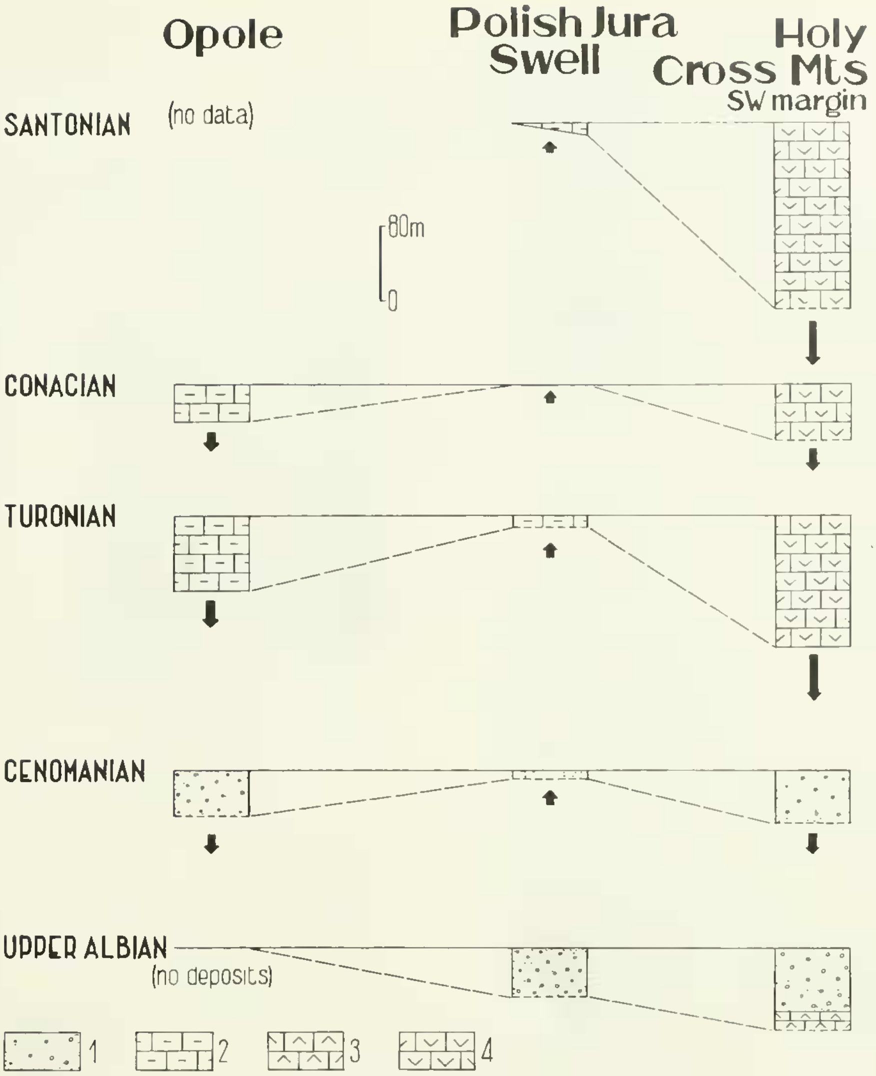

Fig. 5. Comparative diagram of subsidence and uplift during the successive mid-Cretaceous und Upper Cretaceous stages in the Polish Jura Swell and adjacent regions of Opole and of the Holy Cross Mts (cf. fig. 1); detailed explanation in the text.
1 – sands and sandstones; *2* – limestones and marls; *3* – spongiolites and gaizes; *4* – siliceous marls.

HOLY CROSS MOUNTAINS

In the Holy Cross Mts, the mid-Cretaceous transgressive sequence is locally exposed along the so-called Mesozoic margins of the Paleozoic core. Maximum thickness occurs in the north-western region, where it rests upon the deposits of the short-lasting Neocomian trangression (Berriasian till Hauterivian). There it begins with a thick series (up to 140 m) of unfossiliferous, kaolinitic sands (the Biala-Gora Sands) deposited under shallow subtidal conditions (MARCINOWSKI & RUDOWSKI 1980). These sands continue to the north within the Szczecin-Lodz Synclinorium as far as the city of Lodz (SAMSONOWICZ 1948). To the south, the sands or their upper part at least, laterally pass into limonitic sands and sandstones, locally (at Mt. Chelmowa near Przedborz) containing moulds of large ammonites, *Anahoplites* ssp., *Callihoplites patella* SPATH, *C. auritus* (SOWERBY), *C. variabilis* SPATH, *Mortoniceras inflatum* (SOWERBY), *M. pricei* SPATH, indicative of the low-Upper Albian *auritus* Subzone of the *Mortoniceras inflatum* Zone (CHLEBOWSKI, HAKENBERG & MARCINOWSKI 1978).

Further to the south along the south-western Mesozoic margin, the thickness of ?Middle and Upper Albian sandy deposits gradually decreases, and finally they vanish completely (HAKENBERG 1969, 1978). On the other hand, the gaizes with *Neohibolites minimus* (MILLER) and (20 m above) with *N. ultimus* (D'ORB.) (see SPAETH 1971 for taxonomy), which overlie the Biala-Gora Sands, change in this direction into glauconitic sands or friable sandstones with detritus of inoceramid shells, small phosphatic nodules, and (RADWANSKI 1968, 1969b) numerous shark teeth associated with those of reptiles.

The southernmost exposure along that zone, just within the shorezone of the Fore-Carpathian Depression, viz. Mt. Za-

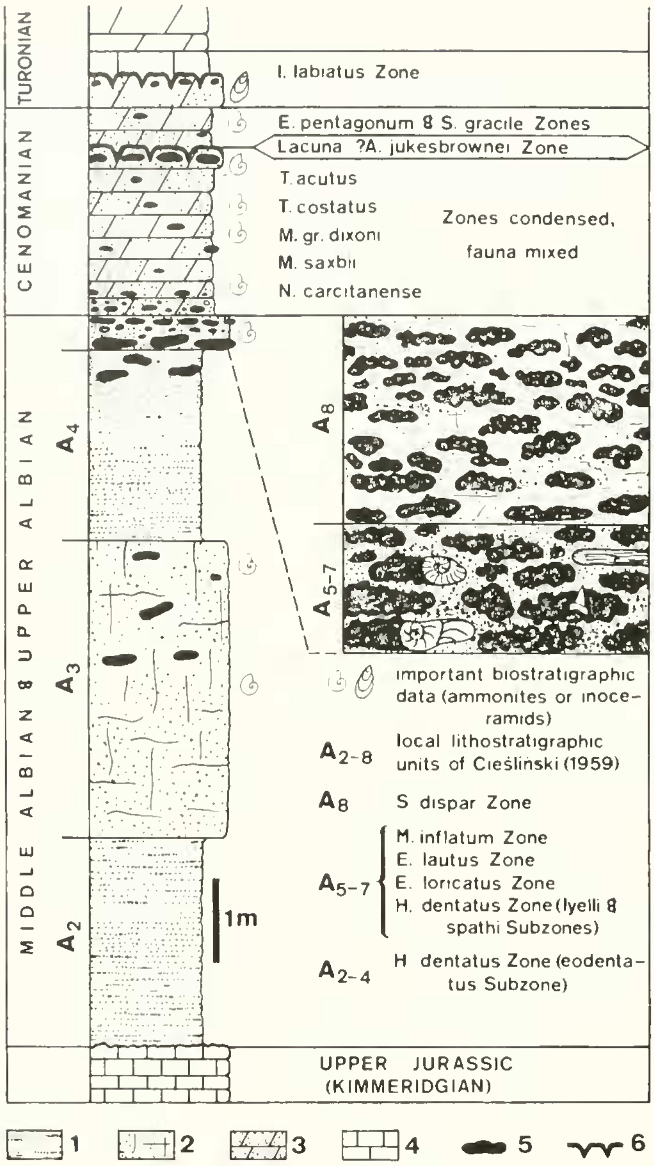

Fig. 6. Detailed section of the mid-Cretaceous transgressive sequence at Annopol-on-Vistula in the Holy Cross sedimentary area. *1* – sands; *2* – quartzitic sandstones; *3* – sandy glauconitic marls; *4* – limestones; *5* – phosphatic nodules and phosphorites; *6* – hardgrounds.

jecza at Skotniki near Busko shows (Radwański 1969a) heavily glauconitic sandstones, pebbly and more compact at the bottom, which rest upon a fissured and locally glauconitized abrasion surface cutting Kimmeridgian limestones. In this exposure the New-Kimmerian angular unconformity is well visible (pl. 2, fig. 4). This is the only outcrop in which the regional tilting is recognizable. The glauconitic sands (about 1.5 m) containing commonly *Neohibolites ultimus* (d'Orb.) and ubiquitous fish bones and teeth (Radwański 1968), pass upwardly into white, chalky siliceous marls with flintstone bands of Turonian age.

The New-Kimmerian regional tilting within the south-western Mesozoic margins of the Holy Cross Mts and subsequent erosion resulted in a truncation of the Upper Jurassic (Kimmeridgian-Tithonian) substrate. It remained more elevated to the south, and consequently, in the overlapping of successive deposits of the mid-Cretaceous cycle. Within the exposures no details of land topography have been recognized. On the other hand, the mid-Cretaceous sedimentation has not been disturbed either by synsedimentary tectonics and/or sedimentary gaps.

Along the north-eastern Mesozoic margins of the Holy Cross Mts, the mid-Cretaceous sandy deposits are distributed more uniformly, slightly thinning to the south, but containing Middle/Upper Albian and Cenomanian ammonites (Cieslinski 1959, 1976; Marcinowski 1980).

The famous locality Annopol-on-Vistula belongs to this sedimentary area (see Samsonowicz 1925, 1934; Cieslinski 1959, 1976; Marcinowski 1980). The sections are well exposed along both Vistula embankments, and in an underground mine (now abandoned, with poor phosphatic ore). They indicate a brachyanticline of Annopol which – situated on the right edge of the Vistula – lies geographically in the Lublin Upland.

At Annopol-on-Vistula Mid-Albian to Lower Turonian sandy or marly-sandy deposits are exposed (fig. 6), evidently condensed in relation to those outside the Annopol anticline (CIESLINSKI 1976). The poorly glauconitic Albian sands rest upon Kimmeridgian limestones, and are overlain by locally quartzitic sandstones, (unit A_3, fig. 6), with *Hoplites (Ischoplites)* sp. (= *Anahoplites* cf. *praecox* SPATH of CIESLINSKI, 1959) indicative of the *eodentatus* Subzone of the *Hoplites dentatus* Zone (OWEN 1971). The sands are capped by the phosphorite bed; it is about 40 cm in average, but locally ranging from nil to some 90 cm, and composed of irregular phosphatic lumps, usually larger and cemented into coke-like bodies in the lower part of this sandy bed (unit A_{5-7}, fig. 6), and smaller and dispersed in more marly and glauconitic matrix in the upper part (unit A_8, fig. 6).

The nature of these phosphorites is similar to that of intraformational breccias: a laminated phosphatic sediment, possibly concretionary in parts, has been crushed into pieces or lumps and has been reworked by hydrodynamic agents, and mixed up with abundant organic remains, pieces of commonly bored wood and diverse invertebrates, associated with bony material of fishes and reptiles (SAMSONOWICZ 1925, 1934; CIESLINSKI 1959; RADWANSKI 1968; COLLINS 1969). All these fossils are more or less phosphatized, some of the worn, glauconitized or encrusted by various epizoans, mostly serpulids; they occur either within the phosphatic lumps or among them. Reworking and redeposition, recognizable also in ammonite moulds (SAMSONOWICZ 1925), evidence the condensation that comprises the ammonite zones of almost the whole Middle and the lower part of the Upper Albian (fig. 6). The ammonite assemblage (CIESLINSKI 1959; MARCINOWSKI 1980), regardless the species previously listed (SAMSONOWICZ 1925, 1934) but never described or illustrated and now lost, contains *Hoplites dentatus dentatus* (SOW.), *H. dentatus robustus* SPATH, *H. escragnolensis* SPATH, *H. latesulcatus* SPATH, *H. vectensis* SPATH, *Anahoplites* cf. *fittoni* (D'ARCHIAC), *Euhoplites* cf. *ochetonatus* (SEELEY), *E.* cf. *boloniensis* SPATH, and *Mortoniceras* cf. *inflatum* (SOW.). The species *Stoliczkaia* cf. *notha* (SEELEY) reported by CIESLINSKI (1959) from the upper part of the phosphatic bed (unit A_8, fig. 6) evidences the topmost zone of the Upper Albian.

Overlying the Middle to Upper Albian phosphorites are Cenomanian sandy glauconitic marls, still containing phosphatic bodies and diverse, more or less phosphatized fossils. *Mariella cenomanensis* (SCHLÜTER), *M. essenensis* (GEINITZ), *Turrilites costatus* LAMARCK, *Neostlingoceras carcitanense* (MATHERON), *Mantelliceras tuberculatum* (MANTELL), *M. saxbii* (SHARPE), *Schloenbachia varians* (SOWERBY), *S. coupei* (BRONGNIART), and *Calycoceras gentoni* (BRONGNIART) indicate the condensed nature of the deposits (about 1.8 m) representing the whole Lower and part of the Middle Cenomanian (MARCINOWSKI 1980). In their upper part about 1.7–1.8 m above the Albian/Cenomanian boundary, a bank of larger phosphatic concretions developed. Most of the concretions are gradually harder towards their tops, at the level of which they are flattened and glauconitized, displaying the nature of the hardground. A stratigraphic gap at the hardground comprises probably the whole *Acanthoceras jukesbrownei* Zone. The Upper Cenomanian deposits (about 0.5 m) with *Schloenbachia lymensis* SPATH and *Actinocamax plenus* (BLAINVILLE) continue into those of the Lower Turonian *Inoceramus labiatus* Zone. The latter is also condensed (0.6 m), in its lower part truncated by another hardground. The facies changes into limestones just above the hardground; this terminates the development of the mid-Cretaceous transgressive sequence.

DEVELOPMENT OF THE TRANSGRESSIVE SEQUENCE

The mid-Cretaceous transgression overwhelmed the Central Polish Uplands quickly but not violently. The land morphology of the Upper Jurassic substrate has been preserved therefore, and not destroyed by progressing abrasion. The weathered waste probably has been completely removed prior to the transgression; its remains, mostly the flint nodules from the Oxfordian butten limestones, have been entrapped locally within depressions. Some of them (e. g. near Mokrzesz, fig. 2), might have reflected the karst morphology of the butten limestones. The allochthonous quartz sands, notwithstanding their local cross-bedding, indicate an uniform sedimentation throughout the larger parts of the Polish Jura and northern parts of the Holy Cross region. Deposition of sand bodies was gradually embracing higher and higher parts of the substratal elevations, and filling up particular depressions (fig. 4). The sequence of sandy deposits is thought to represent an one-cycle filling of the land morphology inundated during the first attack of the mid-Cretaceous transgression. The sequence is terminated either by layers containing *Ophiomorpha nodosa* LUNDGREN burrows (fig. 2) attributable to the inter- and shallow subtidal (WEIMER & HOYT 1964; RADWANSKI 1970), or by widespread erosive channels (pl. 2, fig. 2a–2b) comparable to those formed at present time under shallow subtidal or even intertidal conditions. The discussed part of the basin became then filled by sediments almost to sea level.

The time of the transgression is generally regarded as Middle Albian. It is recognized precisely at Annopol-on-Vistula only, where the *eodentatus* Subzone of the *Hoplites dentatus* Zone is evidenced. Arbitrarily, the underlying poorly glauconitic sands are also included into that zone. In the Polish Jura an inoceramid fauna with *Inoceramus concentricus*, *I. anglicus* and *I. anglicus-crippsi* is indicative of Upper Albian age, near the Albian/Cenomanian boundary. This inoceramid fauna appears in the upper part of the sands. The lower part of the sands is therefore arbitrarily included into the same time interval, with a possible extent down to the uppermost Middle Albian or even to the *Hoplites dentatus* Zone. When appears that the Polish Jura deposition is not so old, it will be consequently evident that the mid-Cretaceous transgression has reached the north-eastern Holy Cross region earlier than that of the Polish Jura. In such a way, the subsidence along the axial zone of the Danish-Polish Trough should be postulated as a factor which could control the first advance of the mid-Cretaceous transgression.

A poor fauna in Upper Albian sandy deposits of the Polish Jura, represented by inoceramids and siliceous sponges (Marcinowski 1974; Malecki 1979) seems to be diagenetically devoid of any aragonitic and thin-shelled calcitic remains. A diversified life at that time however is indicated by moulds of rock-borers of many taxonomic groups preserved in siliceous concretions. Their calcareous cores have been dissolved during diagenesis (Marcinowski 1974, pl. 17, fig. 9).

A comparably rich fauna from Annopol-on-Vistula resisted dissolution due to its earlier, more or less advanced phosphatization. The phosphorites themselves indicate strongly activity of hydrodynamic agents and both sedimentary and stratigraphic condensation. It was commonly postulated that the Annopol area (later the Laramide anticline of Annopol) was rising and forming a submarine high, the Annopol Swell (the Vistula Threshold of Cieslinski 1976), which became responsible for sedimentary disturbances and formation of the phosphorites already at the first stages of the mid-Cretaceous transgression.

The further extent of the mid-Cretaceous transgression is generally regarded as a result of further advance of the sea over the European continent. In the marginal parts of the Central European Basin it might have been caused, also by a rise of waters expelled from the basinal frames by the bulk of Upper Albian sediments deposited within these frames. In any case, the Cenomanian shallow marine sedimentation was very slow, with noticeable signs of further condensation associated with phosphatization, glauconitization, and reworking (figs. 3 and 6). All these processes refer to the Lower and to a part or to the whole Middle Cenomanian. In the best known section at Annopol-on-Vistula, these processes resulted in the formation of a hardground followed by a hiatus probably corresponding to the *Acanthoceras jukesbrownei* Zone (fig. 6). In the Polish Jura, especially in the Cracow Upland, the allochthonous clastic material became coarser and sandy gravelstones appeared either above the Albian sands (pl. 2, fig. 1) or directly upon the Upper Jurassic substrate (pl. 1*A–D)*.

The Upper Cenomanian deposits were laid down under shallow marine conditions, indicated by burrows *Ophiomorpha nodosa* Lundgren, present throughout some sections (fig. 2). In other sections this time interval is represented by gravelstones (fig. 3 and pl. 1*A–D)* or sands. None of these deposits gives evidence for a deepening of marine basins recognized (Hart & Tarling, 1974) in the panglobal scale. It seems that this panglobal phenomenon did not affect the marginal parts of the Central European Basin, presumably resulting by a first tectonic uplift within the Polish Jura basement (fig. 5).

All the Upper Cenomanian deposits record either a considerable decrease or an almost total absence of macrofossils (Marcinowski 1980). This panglobal phenomenon, observed in North America and during deep-sea drilling in the North Atlantic and the Pacific, is referred (Hart & Tarling 1974) to the above-mentioned deepening of Late Cenomanian basins which effected a change in phytoplanktic productivity and calcium carbonate deposition after the mid-Cenomanian non-deposition. However, because this panglobal event has neither influenced the investigated region nor some others from epicontinental areas outside the Central European Basin, it was claimed (Marcinowski 1980) that another reason should be taken into account when discussing the obvious decrease of macrofossils. This may be a greater supply of diverse chemical compounds, both organic and anorganic, to the sedimentary basins from hinterlands and connected with the progressing transgression which reaches its maximum during the early Turonian (Hancock 1975; Rawson & al. 1978; Hancock & Kauffman 1979). Such a supply could probably induce a temporary change in water chemistry of epicontinental seas, detrimental to some organisms which, in turn, could disturb the trophic chains and cause a rapid decrease in macrofaunal density (Marcinowski 1980).

At the Cenomanian/Turonian boundary, the conditions within the Central Polish Uplands were locally disturbed by further Subhercynian tectonic activities. The movements became intense especially within the Cracow Upland (fig. 4), and the tectonic unrest lasted until the Santonian. In the Cracow Upland it primarily resulted in a repeated abrasion of older mid-Cretaceous deposits, and consequently either in the formation of an abrasion surface within Turonian deposits (Alexandrowicz 1954), or in deposition of thin Turonian strata directly upon the Upper Jurassic substrate within some of the tectonic blocks (fig. 4 and pl. 2, fig. 3).

In the northern part of the Polish Jura the tectonic unrest resulted in discontinuities associated with small neptunian dykes or with stromatolites within the *Inoceramus lamarcki* and *Inoceramus costellatus* Zones (Marcinowski & Szulczewski 1972; Marcinowski 1974), the top of which is often a hardground. Overlying marls of Santonian or Lower Campanian age prove a remarkably longlasting period of submarine non-deposition which presumably correspond to tectonic lull of the whole area of the Polish Jura. In the Holy Cross sedimentary area tectonic unrest is recognizable only within the *Inoceramus labiatus* Zone: the overlying deposits display greater thicknesses and a continuous sedimentation until the top of the Upper Cretaceous sequence (Pozaryski 1938). The only hitherto recognized disturbance appears in the Lower Santonian *Actinocamax westfalico-granulatus* Zone when the siliceous marls became glauconitic with small phosphatic nodules (level *e* of Pozaryski 1938), and submarine slumping developed (Radwanski 1960). These both features are thought to be the distant effects of much greater disturbances within the Polish Jura Swell.

AMMONITE BIOGEOGRAPHY

The ammonite faunas of the mid-Cretaceous transgressive sequence are autochthonous in all the investigated sections of the Central Polish Uplands. Any significant transportation of shells is denied by their state of preservation even in areas showing a considerable stratigraphic condensation (Jazwiny, Mokrzesz, Glanow) or combined with evident reworking (e. g., Annopol-on-Vistula). Since a far-distant post mortem drift can be excluded, it is apparent that the recognized ammonites display their biogeographical provenances.

The relatively poor Middle and Upper Albian ammonite assemblage from the condensed deposits of Annopol-on-Vistula as well as the Upper Albian assemblage from Mt. Chelmowa near Przedborz are dominated by representatives of the family Hoplitidae. Thus their affinities to the Boreal Hoplitid Faunal Province is obvious. It is noteworthy that within the Middle and low-Upper Albian condensed deposits of the high-tatric zone in the Tatra Mts (PASSENDORFER 1930) the abundant representatives of Phylloceratidae, Lytoceratidae, Gaudryceratidae, and Desmoceratidae, are associated with fairly common Hoplitidae. The Boreal influences were spreading far into the Tethyan realm extending south of the Central Polish Uplands areas.

All the invastigated Lower to Middle Cenomanian ammonite assemblages of the Central Polish Uplands are more or less uniform. They are dominated by representatives of the boreal genus *Schloenbachia* associated with heteromorphs. They are indicative of nearshore to offshore environments of moderate depths; the life habitats are comparable to those occupied by the ammonite groups *A* and *B* of TANABE & al. (1978, fig. 10; MARCINOWSKI 1980; 311–312).

The boreal nature of the Albian-Cenomanian ammonite faunas is recognizable also for the Sub-Hercynian Basin in Germany, and for Podolia, Southwestern Crimea Highland, Dagestan Caucasus, Mangyshlak and Kopet-Dag in the Soviet Union (MARCINOWSKI 1980). Boreal affinities are moreover displayed by a Lower Cenomanian ammonite fauna from Esfahan in Iran (KENNEDY & al. 1979). Consequently it is concluded that at Early to Middle Cenomanian times the southern boundaries of the Boreal Realm were extended to the south as far as the Zagros tectonic line which makes up the northeastern limit of the Arabian Platform (KENNEDY & al. 1979; MARCINOWSKI 1980). Contrary the Tethyan influence into the Central European Basin were surprisingly weaker at these times (SAMSONOWICZ 1925; MARCINOWSKI 1974).

COMPARATIVE REMARKS ON THE TRANSGRESSIVE SEQUENCE

The mid-Cretaceous transgressive sequence of the Central Polish Uplands is generally regarded as confined to the marginal parts of the Central European Basin. The geotectonic structure and their topography controlled the development of the transgressive sequence both in the terms of paleogeographical limits of the marine invasion, source of supply of clastic material, as well as of synsedimentary tectonics. The sequence is therefore not unique. It bears some evident resemblances to those formed in other regions under similar geotectonic conditions either within the frames of the Central European Basin or outside. Within the frames of the Central European Basin such conditions existed for instance in the Rhenish Massif in Germany, or in the island of Bornholm in Denmark. Outside these frames they are recognizable in Podolia in the Soviet Union, or in the Tatra Mountains in southernmost Poland and adjacent parts of Czechoslovakia. On the other hand marginal parts of the Central European Basin which underwent a different geotectonic evolution, – even if situated near the Central Polish Uplands (e. g. the Sudetes) – show a different pattern of the mid-Cretaceous events. All these regions will shortly be discussed and compared in the following review.

RHENISH MASSIF

The mid-Cretaceous transgressive sequence of the Rhenish Massif (southern flank of the Münster basin) comprises Cenomanian clastic deposits, overlapping the Albian of the Münster basin and encroaching onto the Variscan substrate (HANCOCK, KENNEDY & KLAUMANN 1972). This is the classical area where the mid-Cretaceous littoral structures have firstly been recognized by KAHRS (1927). The sequence is highly condensed, with the Middle Cenomanian probably missing. It yields excellently preserved faunas in protected pockets of the substrate, e. g. the famous fauna of Kassenberg at Mülheim-Broich (KAHRS 1927; HANCOCK, KENNEDY & KLAUMANN 1972; WIEDMANN & SCHNEIDER 1979). The rich ammonite assemblage shows some unique taphonomic (abundant juveniles), paleogeographic (Indo-Madagascan species) and phylogenic (occurrence of *Lewesiceras)* recognitions (WIEDMANN & SCHNEIDER 1979).

ISLAND OF BORNHOLM

The mid-Cretaceous transgressive sequence of Bornholm begins with the Cenomanian basal conglomerate. It has been studied with regard to its transgressive/regressive cycles and its faunal content (RAVN & STOLLEY; for review see: BIRKELUND 1957; MARCINOWSKI 1974; 204–205; CHRISTENSEN 1976; KENNEDY, HANCOCK & CHRISTENSEN 1981).

The Lower Cenomanian basal conglomerate contains phosphatic nodules with reworked Lower and Middle Albian ammonites indicative of earlier transgressive pulses; it continues into the Arnager Greensand of Middle Cenomanian age (KENNEDY, HANCOCK & CHRISTENSEN 1981). Successive in the sequence, but with a sedimentary gap and with phosphatic conglomerates at the bottom is the Arnager Limestone, recently recognized as Upper Coniacian. Overlying with another sedimentary gap follows the Bavnodde Greensand of Lower Santonian age (Birkelund 1957).

This sequence shows a great resemblance to that of the Cracow Upland (Cenomanian basal conglomerates, fragmentary carbonate sedimentation of Turonian or Coniacian age, Santonian greensand) and that of Annopol-on-Vistula (reworked Albian fauna). The difference mostly consists in a greater thickness of the Bornholm sequence, although the island lies within the outer zone of the Border Synclinorium and thus reaches the margins of the Fenno-Sarmatian Shield (Ziegler 1975; Kennedy, Hancock & Christensen 1981). Possibly the block-faulting tectonics along the margins of the Fenno-Sarmatian Shield have been responsible for this stronger subsidence (Kennedy, Hancock & Christensen 1981; 210). Anyway, it is noteworthy that the mid-Cretaceous transgression entered the Bornholm area earlier (Lower Albian) than any part of the Central Polish Uplands.

PODOLIA

The region of Podolia in the Ukraine lies already on the Fenno-Sarmatian Shield, far outside the areas embraced by the Danish-Polish Trough. Nevertheless its mid-Cretaceous transgressive sequence (Albian deposits in local depressions, Cenomanian-Turonian overlapping clastics and carbonates) is of the same kind as that within the Central European Basin. The mid-Cretaceous transgression presumably encroached from the basin to the east onto the stable, cratonic substrate which became inudated by an epicontinental sea.

The mid-Cretaceous transgressive sequence, first studied by Kokoszynska (1931), has recently been revised (Marcinowski 1974: 203–204; 1980: 226–227). It starts, in the classical section of Podzameczek with a greensand layer overlain by a few metres of glauconitic marlstones containing phosphatic nodules and rich faunas. The ammonite assemblage is dominated by schloenbachids (pls. 6–7). It is of a mixed nature and indicates condensations throughout the Cenomanian; condensed are also overlying limestones with scarce phosphatic nodules which contain a mixed fauna of Cenomanian and Turonian age (Pasternak & Gavrilishin 1977).

TATRA MOUNTAINS

Within the Carpathian geosyncline a unique, comparable mid-Cretaceous transgressive sequence appears on the geanticlinal elevation of the high-tatric facies-tectonic zone in the Tatra Mts. This sequence, well exposed both in Poland and Czechoslovakia, has been first recognized by Passendorfer (1921, 1930). The condensed sequence, locally with stromatolites, rests upon eroded and locally karstified Urgonian limestones. It starts with dark green glauconitic limestones containing phosphatic nodules and some exotic root-rafted pebbles. In the classical section at Mt. Giewont a rich ammonite fauna (Passendorfer 1930) indicates the *Hoplites dentatus* Zone; other localities yielded diverse *Douvilleiceras* indicative presumably of an earlier transgression (Passendorfer 1978). The overlying glauconitic marls contain *Mortoniceras inflatum* (Sow.) and *Stoliczkaia dispar* (d'Orb.), and pass upwardly into deep-water Cenomanian marlstones (Passendorfer 1930). The small belemnites from the *Hoplites dentatus* assemblage (Passendorfer 1930) have been recently revised by Spaeth (1971: 58, 62) as *Neohibolites minimus minimus* (Miller) and *N. minimus obtusus* Stolley. The ammonites, represented mostly by families of the Tethyan realm, need further taxonomic investigations. Wiedmann & Dieni (1968) recognized within Passendorfer's material some more taxa and established one new subspecies *Kossmatella (Kossmatella) oosteri* Breistroffer *passendorferi* Wiedmann & Dieni.

SUDETES

The Upper Cretaceous sequence in the Sudetes starts with badly exposed and poorly known Cenomanian greensands (5 to about 50 m). It is dominated by a repeated succession of the marly (Pläner) and coarse-grained sandy (Quader) facies similar to Saxony. The classical sections have been studied by Beyrich, Roemer, Geinitz, Leonhard, Scupin, Andert & Hantzschel, who have presented basic data on the stratigraphy and fauna. The sequences (Cenomanian through to ?lowermost Santonian) differs much from that fo the Central Polish Uplands. They mostly represent fillings of intermontanic basins by more or less local clastic material. For the Inner-Sudetic basin (the Stolowe Mts = Heuscheuergebirge) the Owl Mts (Eulengebirge) supplied the sandy material, deposited as an accumulation platform, migrating towards the epicontinental sea of the Bohemian Massif (Jerzykiewicz 1966a, b; 1967). Within the Nysa graben – during the Coniacian a taphrogeosyncline with remarkably thick (ca. 900 m) series of flysch deposits – the metamorphic massifs of the Eastern Sudetes (Jerzykiewicz 1971) yielded the material. It is thought that all these basins were generally connected with the Central European Basin, although their history was primarily dependent upon regional tectonic framework. Their sedimentary conditions and history were more similar to those on the Bohemian Massif than to those of any other marginal part of the Central European Basin.

CONCLUSIONS

The mid-Cretaceous transgressive sequence starts throughout all these parts of the Central European Basin (Central Polish Uplands and Polish Lowland) with deposits attributable to the *Hoplites dentatus* Zone. The direction of the transgression can be postulated either from the Bornholm area (where the Lower Albian is documented, Kennedy, Hancock & Christensen 1981), or from the Tethyan realm via the Tatra palinspasthic area (as indicated by a *Douvilleiceras* fauna from the high-tatric zone; Passendorfer 1930, 1978). In the first case, a presumed route of the transgression should be suggested along the axial zone of the Danish-Polish Trough, the zone of the greatest subsidence (KUTEK & GLAZEK 1972; CIESLINSKI 1976). It is noteworthy that this axial zone was controlling the extent of the transgression already in the Muschelkalk (GLAZEK & al. 1973). In the case of an Tethyan spreading, it would only explain some faunal influences which are much weaker in the Central Polish Uplands (SAMSONOWICZ 1925; MARCINOWSKI 1974) than in the Rhenish Massif (WIEDMANN & SCHNEIDER 1979). It is therefore concluded that a southward progress of the transgression from the northern (Bornholm) regions is more probable. This explains a more or less uniform development of the mid-Cretaceous deposits throughout the Polish Lowland and their successive onlap onto the Central Polish Uplands; the southern parts (Cracow Upland, southern Holy Cross region) purchased a sedimentary cover in the Cenomanian, and finally even in the Turonian. Anyway, a seaway through the meta-Carpathian arch did exist at the time of transgression, as evidenced by weak Tethyan influences within the ammonite faunas of the Central Polish Uplands, and by the hoplitid expansion into the high-tatric zone. The meta-Carpathian arch itself was subjected to erosion and became the main source of clastic supplies not only for the Central Polish Uplands area, but also for the Carpathian flysch geosyncline (Lgota Sandstones; KSIAZKIEWICZ 1962). The greatest thickness of the meta-Carpathian clastics (Biala-Gora Sands in northern Holy Cross area, up to 140 m) is comparable to that which locally occurred along other margins of the Central European Basin (Arnager Greensand on Bornholm, up to 130 m).

The whole mid-Cretaceous sequence of the Central Polish Uplands – except of the basal sands of the Albian – is condensed; condensation in the higher Albian, the whole Cenomanian, and the Lower Turonian is associated with the presence of glauconite, phosphatic nodules and a phosphorite bed (Annopol-on-Vistula), hardgrounds, small neptunian dykes, and finally of stromatolites. The stratigraphic condensation is expressed both by the reworking of faunas and their mixing, and by the gaps usually marked at and/or within the hardgrounds and stromatolitic horizons. The frequence of the faunas within the sequence is related to the phosphatization. It increases with the bulk of phosphatic nodules. The best preservation show fossils which underwent phosphatization or became entrapped amidst the phosphorite bed (Annopol-on-Vistula). In other cases the fauna became, to a variable extent, taphonomically lost during and/or after their burial.

The peculiar features of the mid-Cretaceous sequence of the Central Polish Uplands are: *a)* thick basal sands of Albian age, developed ununiformly in local (Polish Jura) or regional (northern Holy Cross area) depressions; *b)* locally developed phosphorite bed of mining value (Annopol-on-Vistula); *c)* synsedimentary tectonics realized either by block-faulting (Polish Jura, especially Cracow Upland) or by a more or less continuous uplift (Annopol-on-Vistula) resulting in submarine swells of variable extent, duration, and paleogeographic significance (the Polish Jura Swell, and the Annopol Swell).

The pulses of the mid-Cretaceous transgression onto the Central Polish Uplands realized as follows: *a)* rapid inundation of the diversified topography and a gradual filling of the depressions by allochthonous quartz clastics; *b)* further extent of the transgression and an onlap of the substratal elevations, accompanied by an extreme shallow-water sedimentation; *c)* influx of new waters, deepening of the basin and uniform calcareous sedimentation, locally disturbed by synsedimentary tectonics and hydrodynamic agents related to disturbances in bottom or shoreline morphology; *d)* decline of the transgressive sequence, associated with tectonic lull; filling of the basin presumably to sea level (stromatolites) and progressing long-spanning non-deposition under submerged or locally even emerged conditions (Polish Jura Swell), or deepening of the basin and continuous marly sedimentation until the Santonian disturbances (Holy Cross area). The overlying Santonian to Maastrichtian/Danian marly sediments belong to the younger cycles of the Upper Cretaceous sequence. None of the distinguished pulses within the mid-Cretaceous transgressive sequence is regressive in a common sense; therefore neither regressions nor separate transgressions (as e. g. of the Upper Coniacian recognizable on Bornholm; KENNEDY, HANCOCK & CHRISTENSEN 1981) are indicated. All these pulses are regarded as episodes of one transgression and of one resulting sequence.

It is intriguing that the four distinguished pulses of the mid-Cretaceous transgression, although differing physically or stratigraphically from those of other marginal parts of the Central European Basin (WIEDMANN & SCHNEIDER 1979; KENNEDY, HANCOCK & CHRISTENSEN 1981) are almost identical with those recorded within the Middle Miocene (Badenian) transgressive sequence of the Fore-Carpathian Depression (RADWANSKI 1969, 1970; BALUK & RADWANSKI 1977). Such very pulses (rapid inundation followed by gradual filling, further onlap with shallow-water sedimentation, influx of new waters leading to a slight deepening and associated with calcareous sedimentation filling the basin to sea level) may consequently be postulated as typical also of other transgressive sequences, and reflecting some hitherto not understood general rules of any marine transgression.

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Plate 1

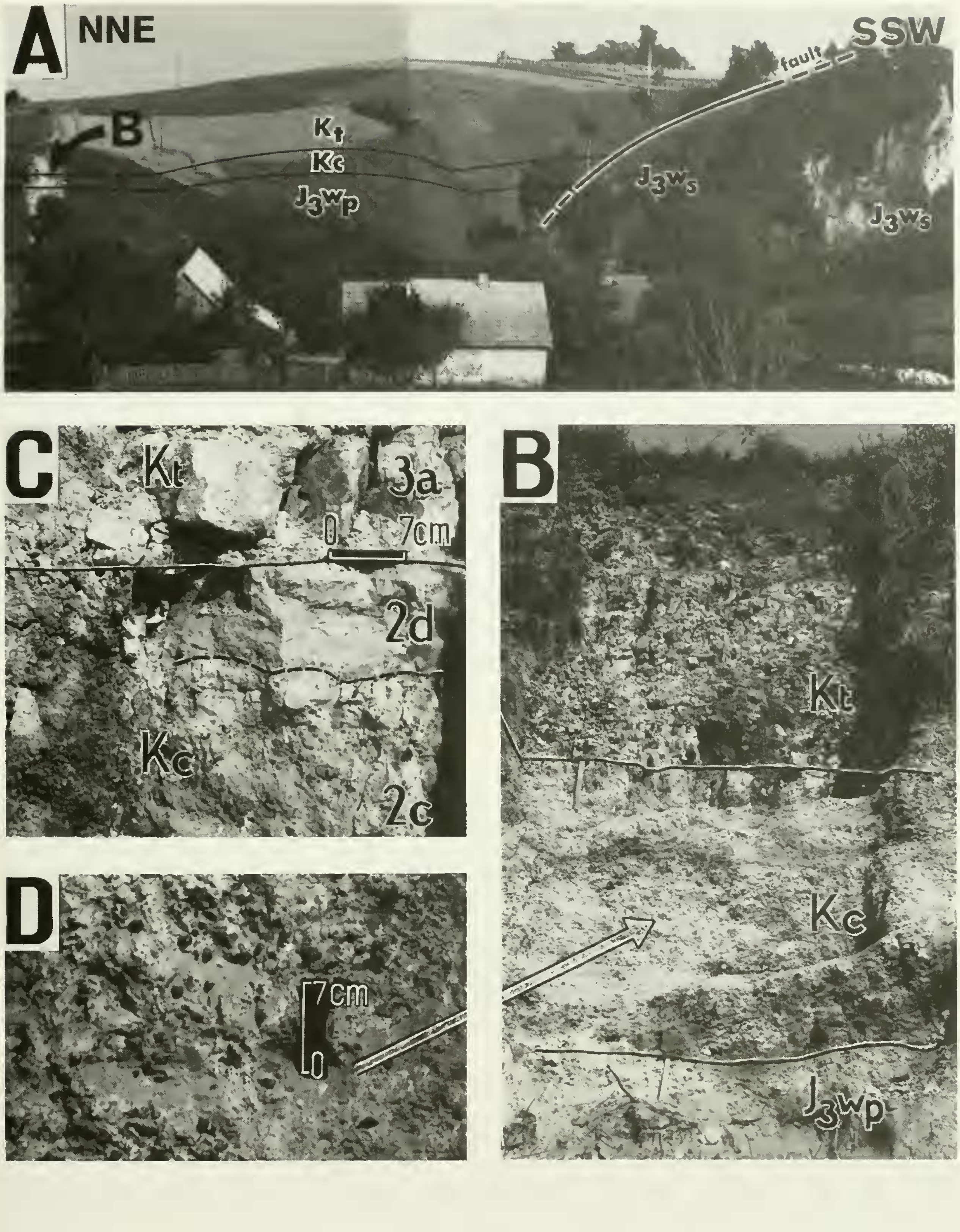
Exposures of the mid-Cretaceous transgressive sequence at Glanow in the Polish Jura.

A. General view, to show the landscape and situation of the mid-Cretaceous sequence within a small Laramide graben; arrowed *(B)* is the trench dig out at the edge of the ravine running to the Dlubnia valley (cf. MARCINOWSKI 1974); J_3w_s – Oxfordian butten limestones; J_3w_s – Oxfordian platy limestones; *Kc* – Cenomanian; *Kt* – Turonian.

B. Section, to show condensed Middle and Upper Cenomanian deposits.

C. Detailed view of the Cenomanian/Turonian boundary (numbers of beds the same as in figs 3–4; in Marcinowski 1974): laminated limestones (bed *2d*) at the top of Cenomanian marly gravelstones.

D. Detailed view of the fossiliferous Middle Cenomanian gravelstones with phosphatic nodules embedded in sandy-marly matrix (bed *2a*).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2c
B
Kt
Kc
J3wp
D
7cm
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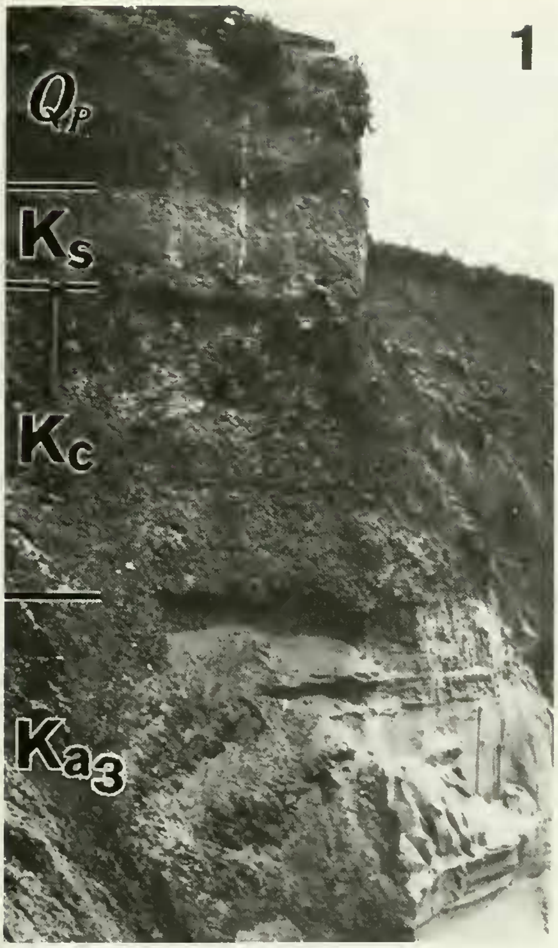
Plate 1

Plate 2

Mid-Cretaceous transgressive sequence in the Polish Jura and the Holy Cross Mts.

1. Section at Korzkiew in the Polish Jura (see fig. 4): Upper Albian sands *Ka_3* overlain by Cenomanian gravelstones *Kc*, and Santonian *Ks* glauconitic marls with phosphatized fauna; *Qp* – Pleistocene loess.
2. Section at Sucha near Glanow in the Polish Jura (see figs. 3–4): Upper Albian cross-bedded, poorly glauconitic sands with diverse sponges and trace fossils, locally cemented into irregular lenses and concretions of siliceous sandstones (numbers of co-sets the same as in MARCINOWSKI 1974): *2a* – Eastern wall of sand-pit, to show a subtidal channel (unit *6*); *2b* – Southern wall of sand-pit.
3. Section at Januszowice in the Polish Jura, near the city of Cracow (see fig 4): Oxfordian butten limestones *J_3w_5* truncated by the transgressive Lower/Middle Turonian sequence *Kt 1–2*.
4. Section of Mt. Zajecza at Skotniki near Busko in the Holy Cross Mts.: Kimmeridgian limestones *Jk* truncated by Cenomanian glauconitic sandstones *Kc*; New-Kimmerian angular unconformity readable.

1



3

4

2a

2b

Plate 3

Diverse invertebrates (cephalopods excluded) from the mid-Cretaceous transgressive sequence of the Polish Jura *(PJ)* and the Holy Cross Mts *(HCM);* all figures magnified 1.5 unless otherwise stated.

Fig. 1a–b.	*Micrabacia coronula* (Golgfuss); Cenomanian, Mokrzesz *PJ*; 1a – top view, 1b – side view.
Fig. 2.	*Serpula proteus* (Sowerby); Cenomanian, Mokrzesz *PJ.*
Fig. 3.	*Lepidorhynchia sigma* (Schloenbach); Cenomanian, Julianka *PJ;* ×2.
Fig. 4.	*Orbirhynchia parkinsoni* (Owen); Middle Cenomanian, Glanow *PJ,* ×2.
Fig. 5.	*Arcuatothyris arcuata* (Roemer); Cenomanian, Mokrzesz *PJ;* ×2.
Fig. 6.	*Terebratulina chrysalis* (Schlotheim); Cenomanian, Mokrzesz *PJ;* ×2.
Fig. 7.	Carapace of *Necrocarcinus labeschii* (Deslongchamps); Upper Albian phosphorites, Annopol-on-Vistula *HCM;* ×2.
Fig. 8.	Claw of *Necrocarcinus labeschii* (Deslonchamps); Upper Albian phosphorites, Annopol-on- Vistula *HCM;* ×2.
Fig. 9a–b.	*Glypheopsis sanctaecrucis sanctaecrucis* Collins; Middle/Upper Albian phosphorites, Annopol-on-Vistula *HCM;* 9a – lateral view; 9b – dorsal view; ×3.
Fig. 10.	*Exanthesis* cf. *labrosus* (Smith); Cenomanian, Mokrzesz *PJ.*
Fig. 11a–b.	*Emarginula althi* Zareczny; Cenomanian, Jazwiny *PJ;* 11a – side view, 11b – anterior view.
Fig. 12.	*Aucellina gryphaeoides* (Sowerby); lowermost Cenomanian, Annopol-on-Vistula *HCM.*
Fig. 13.	*Lopha colubrina* (Lamarck) (= *Alectryonia diluviana* Linnaeus); Cenomanian, Jazwiny *PJ.*
Fig. 14.	*Camerogalerus cylindricus* (Lamarck); Cenomanian, Annopol-on-Vistula *HCM.*
Fig. 15a–b.	*Pyrina ovalis* (d'Orbigny); Cenomanian, Korzkiew *PJ*; 15a – top view, 15b – side view.
Fig. 16.	*Holaster benstedi* Forbes; Lower Cenomanian, Swolszowice *HCM;* nat. size.
Fig. 17.	*Holaster poloniae* Lambert; Cenomanian, Jazwiny *PJ.*
Fig. 18.	*Pygaulus pulvinatus* (d'Achiac); Cenomanian, Korzkiew *PJ.*
Fig. 19.	*Conulus ellipticus* (Zareczny); Lower Turonian, Głanow *PJ.*
Fig. 20.	*Phymosoma cenomanense* Cotteau; Cenomanian, Mokrzesz *PJ.*
Fig. 21.	*Discoides subuculus* (Klein); Cenomanian, Mokrzesz *PJ.*

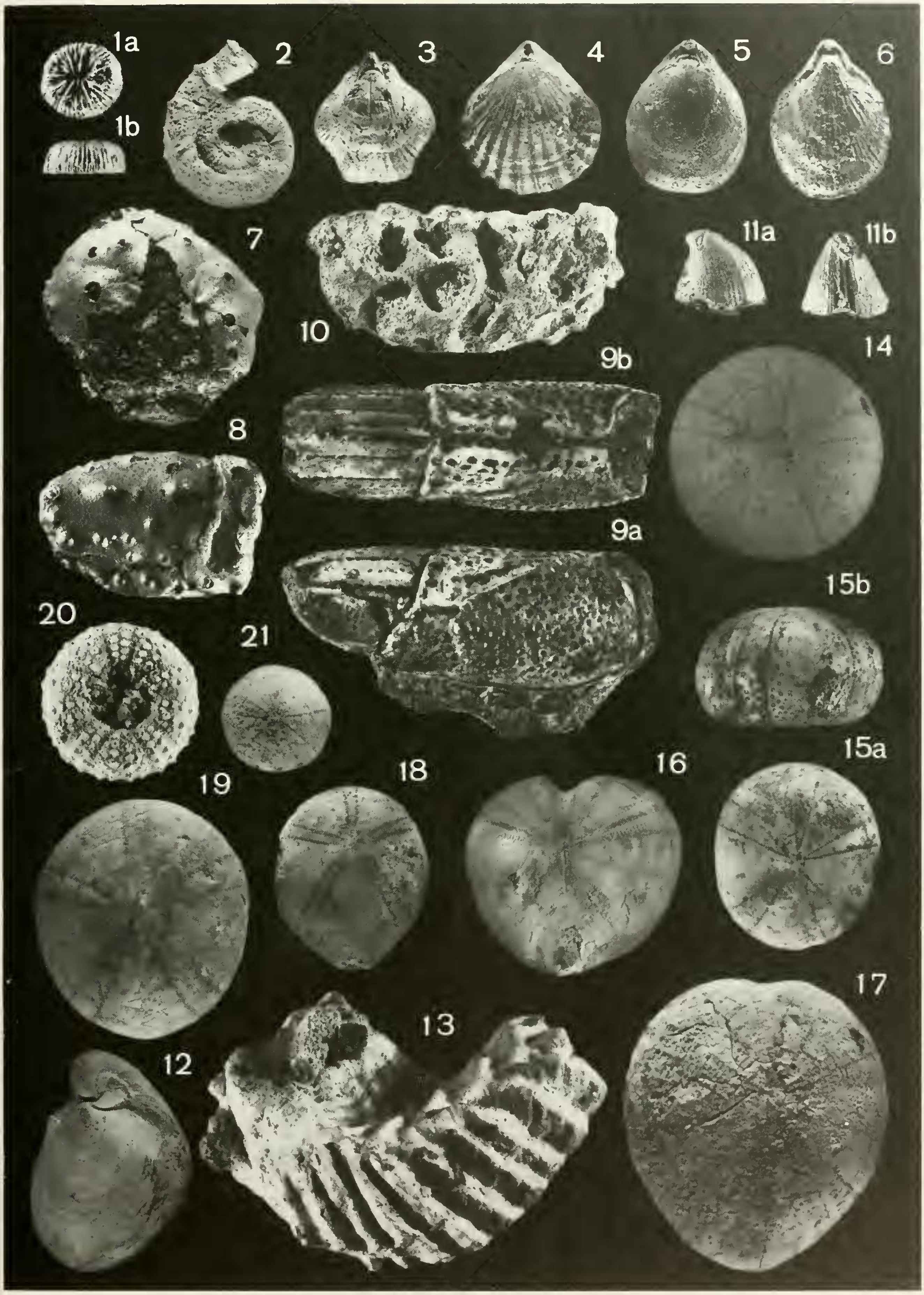

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Plate 4

Ammonites, nautiloids and wood-boring bivalves from the mid-Cretaceous transgressive sequence of the Polish Jura *(PJ)* and Holy Cross Mts *(HCM)*; all figures magnified 1.5 unless otherwise stated.

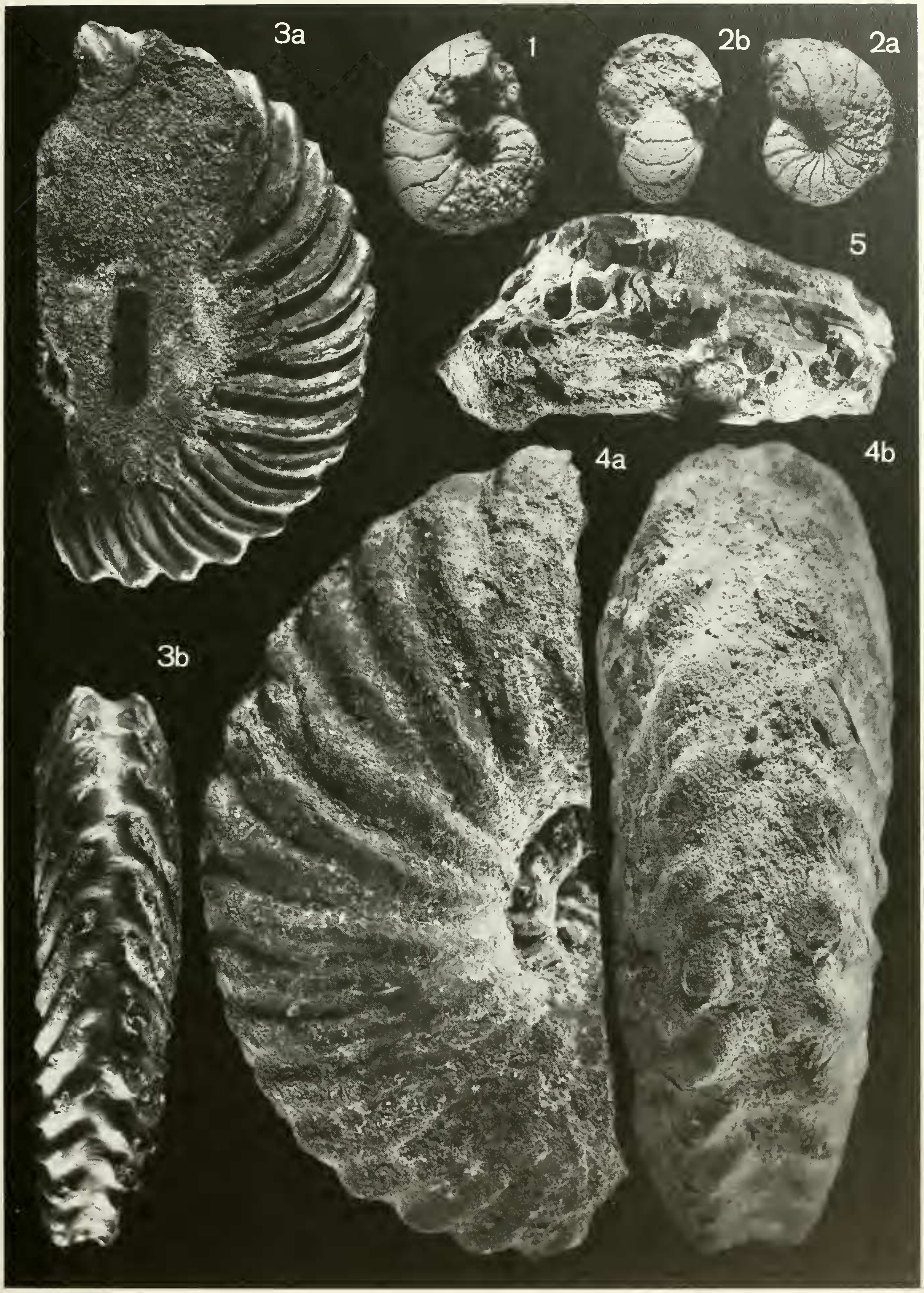
Fig. 1. *Eutrephoceras sublaevigatum* (d'ORBIGNY); Cenomanian, Mokrzesz *PJ*.

Fig. 2a–b. *Eutrephoceras sublaevigatum* (d'ORBIGNY); Cenomanian, Jazwiny *PJ*

Fig. 3a–b. *Hoplites (H.) vectensis* SPATH; Middle Albian phosphorites, Annopol-on-Vistula *HCM;* nat. size

Fig. 4a–b. *Hoplites (H.) dentatus robustus* SPATH; Middle Albian phosphorites, Annopol-on-Vistula *HCM;* nat. size

Fig. 5. phosphatized wood, bored by *Gastrochaena* sp. (? *Gastrochaena amphisbaena* GEINITZ); Middle/Upper Albian, Dabrowka Zablotnia *HCM;* nat. size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2b
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5
4a
4b
3b

Plate 5

Belemnites, ammonites and rhyncholites from the mid-Cretaceous transgressive sequence of the Holy Cross Mts and borehole Lebork near Gdansk (Polish Lowland); all figures of natural size except for Fig. 3 (taken × 1.5).

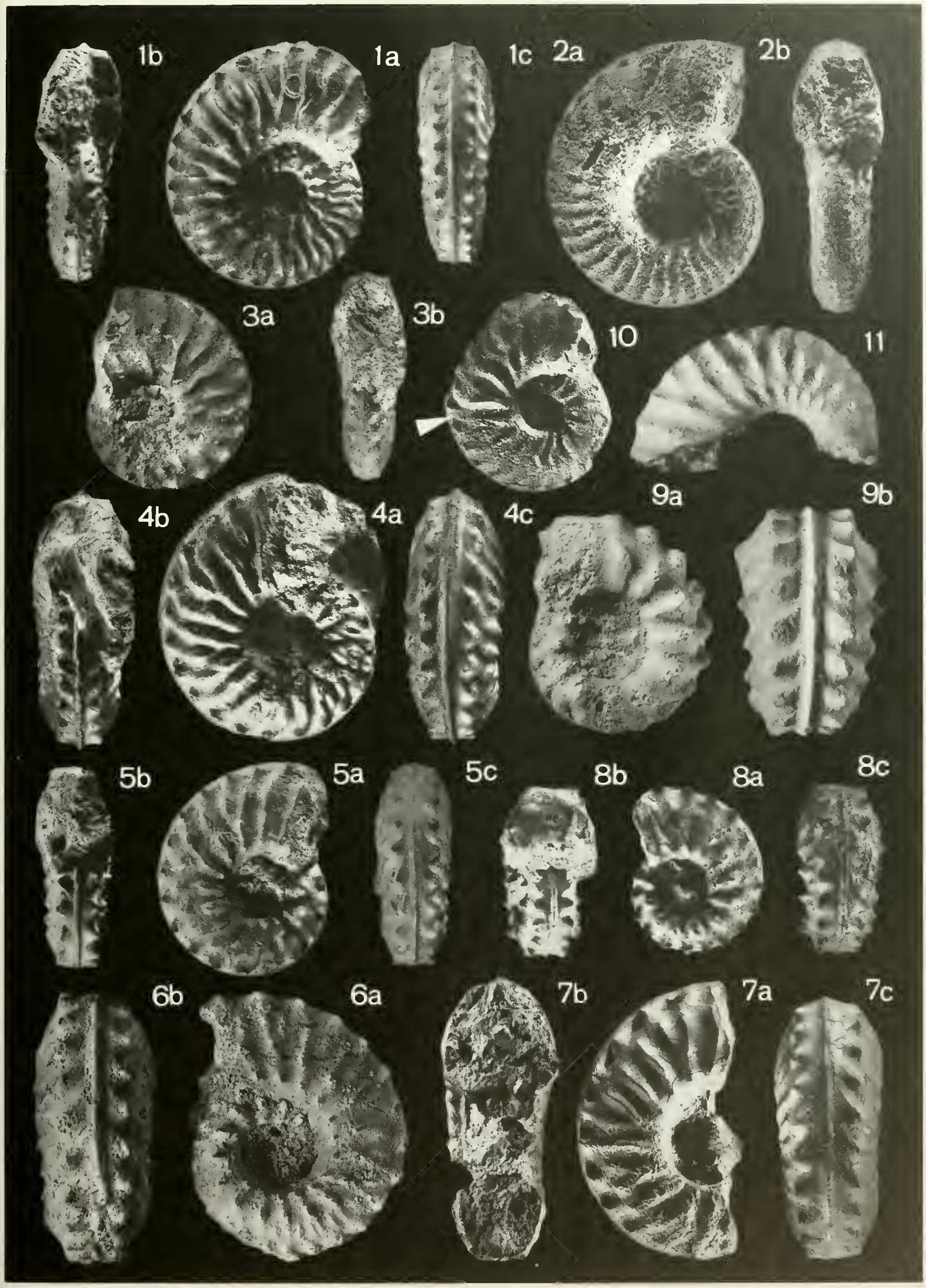
Fig. 1a–c.	*Actinocamax plenus* (BLAINVILLE); Upper Cenomanian, borehole Lebork; 1a – dorsal view, 1b – lateral view, 1c – ventral view.
Fig. 2a–b.	*Neohibolites ultimus* (d'ORBIGNY); Lower or Middle Cenomanian, Annopol-on-Vistula *HCM;* 2a – lateral view, 2b – ventral view.
Fig. 3a–b.	apical part of a rhyncholite; Middle or Upper Albian, Jakubowice near Annopol-on-Vistula *HCM;* 3a – outer view, 3b – inner view.
Fig. 4.	*Hoplites (H.) escragnollensis* SPATH; Middle Albian, Annopol-on-Vistula *HCM.*
Fig. 5a–b.	*Hoplites (H.) dentatus dentatus* (SOWERBY); Middle Albian, Annopol-on-Vistula *HCM.*


1a
1b
1c
3a
3b
4
2a
2b
5a
5b

Plate 6

The *Schloenbachia* species from the Cenomanian deposits of the Central Polish Uplands and Podolia; all figures of natural size except for Figs 6, 9 and 11 (taken ×1.5).

Fig. 1a–c.	*Schloenbachia varians* (SOWERBY) *subvarians* SPATH; Podzameczek in Podolia.
Fig. 2a–b.	*Schloenbachia varians* (SOWERBY) *subvarians* SPATH; Mokrzesz *PJ*.
Fig. 3a–b.	*Schloenbachia varians* (SOWERBY) *subtuberculata* (SHARPE); Annopol-on-Vistula *HCM*.
Fig. 4a–c.	*Schloenbachia varians* (SOWERBY) aff. *subtuberculata* (SHARPE) transitional to *S. varians varians* (SOWERBY); Podzameczek in Podolia.
Fig. 5a–c.	*Schloenbachia varians* (SOWERBY) *subtuberculata* (SHARPE); Podzameczek in Podolia.
Fig. 6a–b.	*Schloenbachia varians varians* (SOWERBY); Jazwiny *PJ*.
Fig. 7a–c.	*Schloenbachia varians varians* (SOWERBY); Annopol-on-Vistula *HCM*.
Fig. 8a–c.	*Schloenbachia varians varians* (SOWERBY); Podzameczek in Podolia.
Fig. 9a–b.	*Schloenbachia varians* (SOWERBY) *ventriosa* STIELER; Mokrzesz *PJ*.
Fig. 10.	*Schloenbachia varians* (SOWERBY) *subplana* (MANTELL); Annopol-on-Vistula *HCM;* arrowed is the end of the phragmocone.
Fig. 11.	*Schloenbachia* sp. pathological form close to *S. intermedia* (MANTELL); Mokrzesz *PJ*.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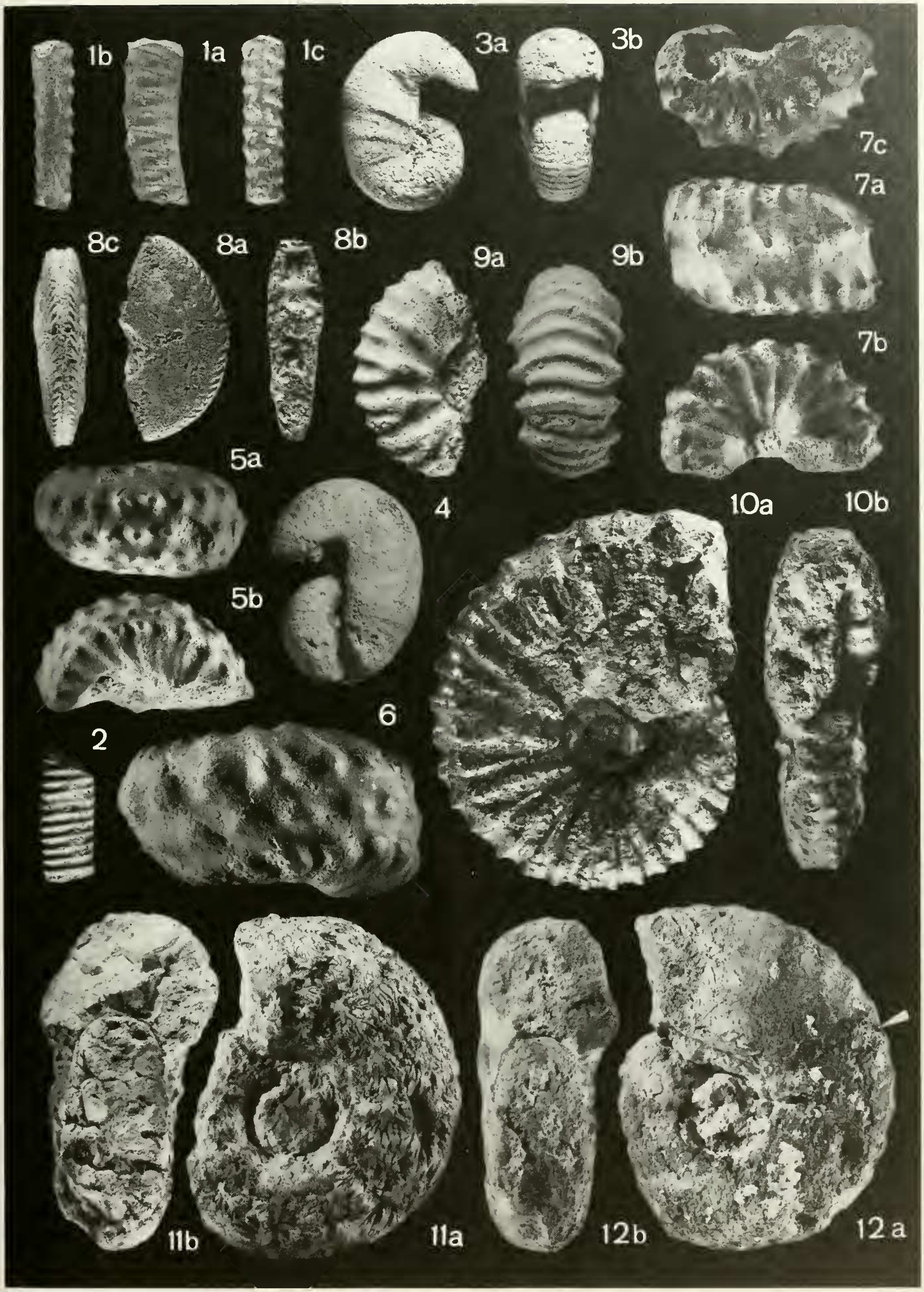
7b
7a
7c

Plate 7

Ammonites from the Cenomanian and Turonian deposits of Central Polish Uplands and Podolia; all figures magnified 1.5 unless otherwise stated.

Fig. 1a–c.	*Idiohamites alternatus vectensis* SPATH; Cenomanian, Annopol-on-Vistula *HMC*; 1a – lateral view, 1b – dorsal view, 1c – ventral view.
Fig. 2.	*Hamites* sp.; Cenomanian, Mokrzesz *PJ;* ×2
Fig. 3a–b.	*Scaphites (S.) obliquus* SOWERBY; Cenomanian, Krasice *PJ*.
Fig. 4.	*Scaphites (S.) obliquus* SOWERBY; Cenomanian, Mokrzesz *PJ*.
Fig. 5a–b.	*Mariella (M.) lewesiensis* (SPATH); Cenomanian, Annopol-on-Vistula *HCM;* 5a – outer face of the whorl, 5b – lower whorl surface.
Fig. 6.	*Mariella (M.) lewesiensis* (SPATH); Cenomanian, Mokrzesz *PJ*.
Fig. 7a–c.	*Neostlingoceras carcitanense* (MATHERON); Cenomanian, Annopol-on-Vistula *HCM;* 7a – outer face of the whorl, 7b – lower whorl surface, 7c – upper whorl surface.
Fig. 8a–c.	*Hyphoplites campichei campichei* SPATH; Cenomanian, Mokrzesz *PJ*.
Fig. 9a–b.	*Calycoceras (Lotzeites)* aff. *lotzei* WIEDMANN; Cenomanian, Jazwiny *PJ*.
Fig. 10a–b.	*Mantelliceras tenue* SPATH; Cenomanian, Podzameczek in Podolia; nat. size.
Fig. 11a–b.	*Lewesiceras peramplum* (MANTELL), inner (juvenile) whorls of the large form; Turonian, probably *Inoceramus costellatus* Zone, Bocieniec *PJ;* nat. size.
Fig. 12a–b.	*Lewesiceras peramplum* (MANTELL), adult specimen (small form) with a fragment of the final body chamber (arrowed is the end of the phragmocone); Turonian, probably *Inoceramus costellatus* Zone, Bocieniec *PJ;* nat. size.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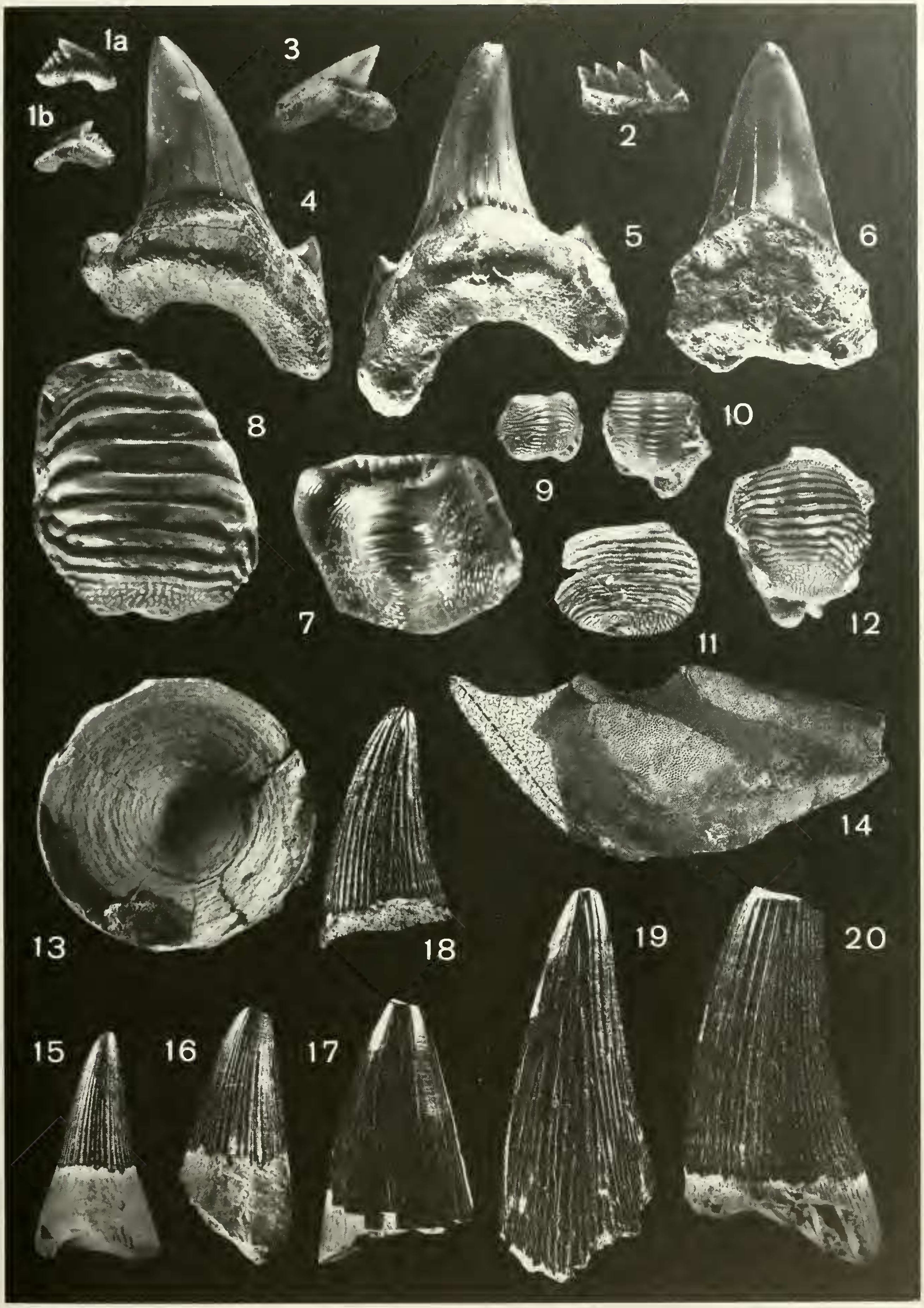
12b
12 a

Plate 8

Fish and reptile remains from the mid-Cretaceous transgressive sequence of the Polish Jura *(PJ)*, Holy Cross Mts *(HCM)*, and borehole Bystrzyca near Lublin.

Fig. 1a–b.	*Galeorhinus minutissimus* (ARAMBOURG); Lower Turonian, borehole Bystrzyca; 1a – outer view, 1b – inner view, ×3.
Fig. 2.	*Notidanus microdon* AGASSIZ; fragment of lateral tooth – principle cusp with anterior serration (weakly visible; indicated by a leader) and three secondary cusps – of the right lower jaw; uppermost Albian, Celestynow *HCM;* outer view, ×2.
Fig. 3.	*Squalicorax falcatus* (AGASSIZ); lateral tooth; Cenomanian, Mokrzesz *PJ;* inner view, ×2.
Figs. 4–5.	*Otodus appendiculatus* (AGASSIZ); Middle/Upper Albian phosphorites, Annopol-on-Vistula *HCM;* inner views, ×2.
Fig. 6.	*Oxyrhina mantelli* AGASSIZ; Middle/Upper Albian phophorites, Annopol-on-Vistula *HCM;* inner view, ×2.
Fig. 7.	*Ptychodus mammillaris* AGASSIZ; lowermost Cenomanian, Sobkow *HCM;* crown view, ×2.
Fig. 8.	*Ptychodus polygyrus* AGASSIZ; Lower Turonian, Mydlniki *PJ;* crown view, ×2.
Figs. 9–12.	*Ptychodus decurrens* AGASSIZ; crown views of the teeth from lateral *(III* or *IV)* row of the upper jaw (fig. 9), lateral *(II* or *III)* row of the upper jaw (fig. 11), and lateral *(I* or *II)* row of the lower jaw (figs 10 and 12); Upper Cenomanian, Glanow *PJ;* ×2.
Fig. 13.	Vertebra attributable to *Ptychodus* (cf. WOODWARD 1912, pl. 52, figs. 6 and 16); Middle/Upper Albian phosphorites, Annopol-on-Vistula *HCM;* 1.5.
Fig. 14.	Right mandibular plate of the chimaeroid *Ischyodus thurmanni* PICTET & CAMPICHE; Middle/Upper Albian phosphorites, Annopol-on-Vistula *HCM;* inner view, nat size.
Figs. 15–16.	Ichtyosaurs *Myopterygius campylodon* (CARTER); Middle/Upper Albian phosphorites, Annopol-on-Vistula *HCM;* ×1.5.
Figs. 17–20.	Sauropterygians *Polyptychodon interruptus* OWEN; one of the teeth displays vanishing ridges (fig. 17); Middle/Upper Albian phosphorites, Annopol-on-Vistula *HCM;* nat. size.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